INTERACTIONS AND PRECIPITATIONS IN DILUTE TERNARY Fe Sb M ALLOYS (M = Ti, V, Cr, Mn, Co, AND Ni)

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We summarize the results of a systematic investigation of the chemical interactions in ternary iron based alloys including 3d transition metals and antimony impurities at typical concentration levels of 1 at.%. We establish a correlation between the presence of these interactions in the solid solution and the solubility of antimony as a function of the nature of the 3d element. The precipitation of antimony rich phases is detected through ^{121}Sb Mössbauer resonance. The results on antimony solubility limits are analyzed in terms of a thermodynamical model of regular solution, depending on the Sb - M interaction energies in the precipitated phase.

Large interaction effects between Sb-Ni and Sb-Ti in the ternary solid solution have been evidenced previously from studies of residual resistivity /1, 2, 3/ and N.M.R. at Sb nuclei /4, 5/. No such behaviour was observed between Sb and Cr /1, 2, 4/. Corresponding investigations are in progress for the other 3d elements : V, Mn, Co.

Correlated changes in the solubility are expected to occur as a consequence of chemical interactions between solutes. The ^{121}Sb Mössbauer resonance appears as a powerful technique to investigate the solubility limits in such dilute ternary alloys. The precipitated phase is characterized by both its hyperfine parameters (hyperfine field and isomer shift) and its X-ray diffraction lines. Ternary Fe Sb M alloys (M = Ti, V, Cr, Mn, Co, Ni) containing one percent of Sb and three percents of M element were investigated in two different thermodynamic states, corresponding respectively to annealings at 900°C (some minutes) and at 500°C (five days), then followed by quenching down to room temperature. In general the magnetic states of antimony atoms are quite different in the dilute solid solution and in the precipitate (Fig. 1). Thus it is possible to determine the proportion of antimony atoms in each phase from the relative intensities of the Mössbauer subspectra corresponding to the two nequivalent sites. A detailed examination of X-ray patterns gives complementary informations on the

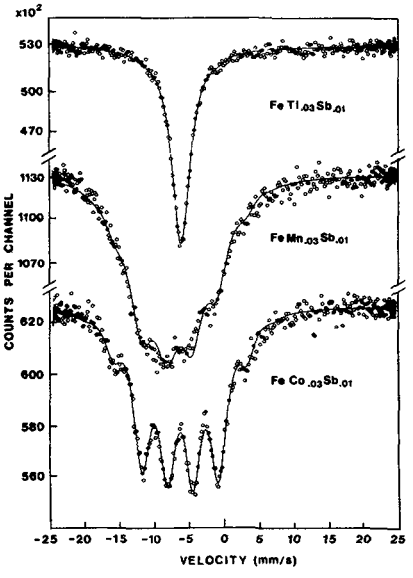

Fig. 1 : ^{121}Sb Mössbauer spectra of $FeSb_{0.01}M_{0.03}$ alloys annealed at 500°C. The $FeSb_{0.01}Co_{0.03}$ spectrum is typical for solute Sb atoms in Fe Sb M solid solution.

distribution of M element among the two phases. In the considered ranges of temperature and concentration, we have observed strong decreases of antimony solubility with Ti, Mn, Ni, whereas no effect was detected with V, Cr, Co solutes. Phase characterization was successful in two cases, namely $(Ni_{55-x}Fe_x)Sb_{45}$ ($x < 0.23$) with hexagonal Ni As structure and $Mn_{2-x}Fe_xSb$ with Fe_2As structure. In both cases, the relative interaction energies $\alpha'_{MSb} = \alpha_{MSb} - \alpha_{FeSb} - \alpha_{FeM}$ are deduced from these solubility data in a regular solution model. Only an order of magnitude for α'_{TiSb} and upper limits for V, Cr, Co are obtained. When crossing the 3d row of the periodic table, it is found that the interaction energies α'_{MSb} between antimony and transition solutes in iron have a typical parabolic shape, except for a strong singularity for Mn (Fig. 2). Other consequences of

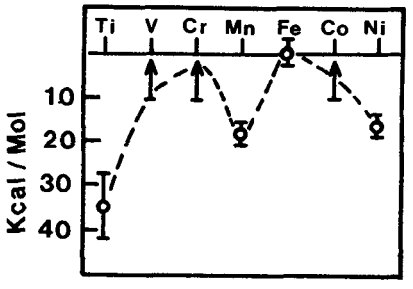

Fig. 2 : Orders of magnitude of the SbM interaction energies in dilute Fe Sb M alloys versus M.

such interactions are short range order effects in the solid solution /1, 2, 4, 5/, and an increase of Sb and M cosegregation on free surfaces or on grain boundaries as demonstrated elsewhere /7, 8/.

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